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Abstract

This paper presents a model of a developing economy with three sectors—a modern sector producing products and services, a traditional sector producing agricultural goods, and a third sector providing energy. Modern and energy sectors are assumed to be demand-constrained; the agricultural sector is supply-constrained. Through the supply constraint, the price-clearing agricultural sector can impose an inflationary barrier on growth. Further, emphasis is placed on the sources of productivity growth. Specifically, higher energy intensity rather than increases in energy productivity enable labor productivity growth, with the attendant complications for "green growth."

ملخص

تعرض هذه الورقة نموذجا لاقتصاد نام مع ثلاثة قطاعات: قطاع حديث ينتج منتجات وخدمات، قطاع تقليدى ينتج السلع الزراعية ، وقطاع ثالث لتوفير الطاقة. ويفترض أن القطاعات الحديثة والطاقة مقيدة بالطلب ، والقطاع الزراعي مقيد بالعرض . ومن خلال قيد العرض ، يمكن للقطاع الزراعي فرض حاجز التضخم على النمو من خلال سعر المقاصة. كذلك، يتم التركيز على مصادر نمو الإنتاجية. وعلى وجه التحديد، ارتفاع كثافة الطاقة بدلا من الزيادات في الطاقة الانتاجية يعمل على تمكين العمالة ونمو الإنتاجية ، مع التعقيدات المصاحبة ل "النمو الأخضر."

1. Introduction

The defining characteristic of many developing countries is structural heterogeneity—the existence of modern production activities side by side with informal, traditional activities (Prebisch (1959), Polanyi-Levitt (2005)). The fundamental policy challenge for developing countries is to provide productive employment opportunities for often still fast growing populations and to raise labor productivity. If GDP growth is strong enough, transfer of labor from low productivity to high productivity activities can support a virtuous circle of development and growth (Kaldor (1978), Ocampo (2005)). Generating employment in modern high productivity activities is difficult enough. It can be further complicated for several reasons, some of which have been raised for decades in the field of development economics.

First, a surge in labor productivity in modern activities can reduce demand for labor, and hence increase the share of workers in informal activities (Rada (2010)). Further, growth of modern activity employment, rural-urban migration and other global factors can lead to upward pressure on agricultural prices (Lewis (1954), Harris and Todaro (1970), and Kalecki (1976)). The resulting decrease in modern sector real wages in terms of necessary agricultural goods can choke off an expansion, especially when external demand is weak or export capacities are underdeveloped (Taylor (1983)).

These issues have regained prominence in the ongoing debate on macroeconomic development policies. Despite strong growth performances, several so-called success stories show mixed employment pictures. China and India are only the two largest developing countries where jobless growth in the wake of the global downturn at the turn of the century appears to have taken hold. In both countries, the share of informal sector employment in total employment is rising. High commodity prices, and specifically high prices of food and staples continue to threaten livelihoods and depress real incomes in the Global South, even if they have receded from their highs in the developed world.

Further, increasing the supply of energy and related infrastructure is of crucial importance for development prospects, but the technological, knowledge-related and cost impediments to quickly adopt high productivity designs are often considerable. High emission energy provision is then the only feasible option, and the development process will be accompanied by a rise in (fossil) energy per unit of labor (Ocampo et.al. (2009)).

Growth of average labor productivity can *ex-post* be decomposed into growth of energy productivity (GDP per unit of energy), and growth of energy intensity (energy per unit of labor)—and the latter has historically dominated the former. Using a structuralist model of development with labor transfer, we illustrate here that a developing country *must* rely on growth of energy intensity to support growth of labor productivity.[1]

More specifically, we discuss a simple three sector model that augments a fairly standard dual economy model with an energy-providing sector, and apply it to Egypt. Agriculture is supply constrained, but output in industry is demand-driven, and affects labor productivity through the well-known Kaldor-Verdoorn channel. To capture as well the link from energy per unit of labor to labor productivity, we add energy intensity in the productivity rule. Our intent is to investigate the linkages and bottlenecks between these three sectors, and results match stylized facts for Egypt: (1) energy productivity growth is flat and not correlated with labor productivity growth, and (2) energy intensity growth is positive and positively

[1] Economic models of climate change commonly are intertemporal full employment models of the long run á la Ramsey. Stern (2007) and Nordhaus (2008) are two important references. See Rezai et.al. (2009) for a careful approach to this type of modeling. We are taking a different approach here; we do not attempt to model damage and mitigation.

correlated with labor productivity growth. In that sense, the analysis here is only descriptive; it illustrates that economic development comes with energy intensification.

Ultimately, this result is driven by the country"s given input-output matrix. Since that technique is—broadly—in place for a decade or longer, the model can be interpreted to apply to the medium run. Crucially, it is not a model of the long run, and cannot speak to mitigation. In the next section (2), we discuss some stylized facts on Egypt to motivate our analysis, followed by a presentation of the model (3), simulations and analysis (4) and conclusions (5).

2. Structural Change and Economic Performance in Egypt

Development requires structural transformation towards high-productivity, high value-added activities. Manufacturing in particular has the potential to deliver increasing returns to scale and overall productivity growth through spillovers and dynamic linkages. Agricultural and primary activities are usually subject to decreasing returns and therefore can present a drag on productivity growth and growth in general. However, industrialization and structural transformation is impossible without an expansion of output and productivity in the agricultural sector. Provision of affordable foodstuffs is crucial to alleviate poverty. Further, inflation of food prices has negative effects on external competitiveness.

In this section we examine indicators of structural transformation and economic performance of the Egyptian economy for the last four decades. We follow it up by a discussion of structural features of the economy based on a 1996/7 SAM.

Agriculture and primary activities have shrunk from 30 per cent of GDP in 1970s to 15 per cent by 2000s while manufacturing and services gained 5 and 9 percentage points respectively over the period. A closer examination of growth dynamics based on a simple decomposition of GDP growth by sectors further reveals that manufacturing and agriculture's contribution to growth has steadily increased over time. See Figure 1.[2] The service sector's contribution to growth, on the other hand, has declined between the 1980s and 2000s despite the rise in the sector's weight in the overall economy. Slow growth of labor productivity in services is one reason, that the new services jobs tend to be low-productivity and possibly informal is another. Since the 1970s overall economic growth has as well benefited significantly less from mining activities. In this case, the cause has to be seen in large fluctuations of oil prices, as documented by, for example, UNDP (2009).

Figure 2 presents a decomposition of growth by institutional sources of demand. Household expenditures make up the largest share of demand followed by gross fixed capital formation (GFCF). Net exports have been negative for most years prior to the 2000s. We can also decompose economic growth by sources of demand. As figure 2 shows, household consumption and gross investment appear as the main drivers of economic growth. Government spending shows a minor contribution, and net exports acted as a drag on growth in the 1970s. The positive contribution of net exports to growth since the 1980s has been fairly small.

Figures 3 and 4 complement the discussion above. The service sector's share of total employment has risen over the period considered—agriculture share is falling, and industry is stagnant. Labor productivity, on the other hand, rose most strongly in industry, and more moderately at lower levels in services and agriculture.

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[2]Aggregate value added is calculated by summing value added across sectors, $X = \sum_{i=1}^{n} X_i$. Total differentiation of this expression with respect to time allows us to write the growth rate of value added as a weighted average of sectoral growth rates in value-added, $\hat{X} = \sum_{i=1}^{n} \theta_i \hat{X}_i$, where θ_i is each sector"s share in overall value-added.

For the simulation exercises we use a Social Accounting Matrix (SAM) from El-Said et.al. (2001) with a base year of 1996/7. We aggregate the SAM, shown in Table 1 below, to three sectors and three households. The three sectors are the t-sector, which includes industry and services; the n-sector, which includes agriculture, and the e-sector, which provides energy.[3] The traditional sector in our framework includes all agricultural and husbandry activities except food processing, which here is considered part of the industry. Energy covers petroleum-related and electricity producing activities.

At this point, a disclaimer is in order. Our SAM has several drawbacks. First, it is relatively old. Second, it does not disaggregate services and industry in modern activities. Third, it does not account for informal activities. However, given the focus of this paper—a theoretical investigation of stylized links between energy use, supply constraints and development—we hope that these are acceptable.

We aggregate the ten households of the SAM in El-Said et.al. (2001) into modern and traditional households using the source of income as a criterion. Traditional households, for example, receive the income of all factors of production—labor, capital and land—from agricultural and husbandry activities. We label them N-households. In the modern t and e-sectors, we distinguish between labor and capital incomes and assume wage-earning and profit-earning households.[4] We label wage-earners the T-households, and profit-earners the C-households. (T-households receive wage income from both the industry and energy sector, as do C-households for profits.) The numbers in Table 2 show that capital income going to the traditional sector represents about 8 percent of total profits in the economy, while traditional labor receives 15 percent of economy-wide wages. Together with income from land, agricultural activities captured 18 percent of the Egyptian national income in 1996/7.

Final demand consists of household consumption, government spending, exports and gross fixed capital formation. In this paper, we make several simplifying assumptions—none of which fundamentally change the model. We assume that capitalist households do not consume. They are as well the only households that save; government spends only on the modern good; exports consist of modern goods and oil; and industry provides the only investment good.

We divide final consumption of modern, traditional and energy goods into consumption by traditional and modern households respectively using the following methodology. We first calculate the weights of traditional and modern households' incomes in total household income using dissagregated data on types of households' incomes. These weights are then used to divide final household consumption into consumption of traditional and modern good by traditional and modern households. For example consumption of agricultural or traditional goods by the traditional household is calculated as:

$$C_N^N = C_N \left(\frac{w_N}{\sum_j y_j} + \frac{\pi_N}{\sum_j y_j} + \frac{rent}{\sum_j y_j} \right) \quad (1)$$

where C_N is total consumption of good N by the household sector, w and π are wages and profits, y_j is the type of income j, and N, T are notations used for the traditional or n-sector and modern or t-sector sector respectively.

[3]The terminology here follows the time-tested *traded, non-traded* distinction. While our n-sector, in accordance with the facts on the ground in Egypt does import, it does not feature exports. Throughout the paper, we will use the labels t-sector,industry and n-sector,agriculture,traditional interchangeably. The label *modern* activities refer to t and e-sector production, since e-sector activities are assumed to be large-scale operations.

[4]Wage-earning households do receive transfers of profits from businesses. For simplicity, we abstract from these; meaning that part of profit income is suppressed in the SAM.

Table 2 summarizes a few general indicators of the Egyptian economy"s structure. In 1996/7 industries and services contributed 78 per cent of gross value-added compared to 16 per cent and 6 per cent by agriculture and energy, respectively. The bulk of final demand or 57 percent went to consumption by the household sector. As expected, demand distribution by type of goods favored goods and services. Households spent 82 per cent of their budget on t-sector product, 17 per cent on n-sector product, and the rest on energy consumption. Unlike most of the previous years, Egypt had a slight trade balance surplus in 1996/7 of almost 2 per cent of GDP. Gross fixed capital formation was relatively solid and represented 17 percent of GDP.

Table 3 provides the output multiplier matrix—the Leontief-inverse. It allows us a more in-depth analysis of the structural linkages and final demand effects. The modern sector has the largest impact on the economy through its overall multiplier of 1.65, implying that a unit increase in final demand for t-sector product leads to an overall increase in gross output of 1.65. The relevant figures for the traditional and energy sectors are 1.42 and 1.30. As expected, the sectors' own multipliers—the diagonal elements of the two matrices—are larger than one suggesting a significant impact of final demand in each sector on its own output.

How about effects across sectors? Both the traditional and energy sector appear to be more dependent on industries and services. A unit increase in the demand for agricultural goods creates a demand for modern sector's product of 0.21 units, while a rise in the consumption of energy leads to a demand of 0.25 units for the t-sector good. At the same time output in the n-sector gains 0.11 units following a rise of one unit in modern sector's final demand. Energy, on the other hand, does not benefit much from a rise in final demand in either the modern or the traditional sectors. See the third row of Table 3. This suggests a relatively low energy intensity of economic activities in the Egyptian economy.

3. The Model

The characteristic feature of the model is that the modern t and e-sectors are quantity-clearing, hence demand-constrained, and the agricultural n-sector is price-clearing or supply-constrained.

Industry and services—the t-sector—are structurally similar to industry and services in advanced economies. Large firms with significant market shares produce with excess capacity, enjoy pricing power, and satisfy current demand X_t by varying their rates of utilization. Higher rates of utilization necessitate hiring. The growth rate of employment, however, is smaller than the growth rate of value added Y_t; in the short run due to labor hoarding, and in the medium run due to Kaldor-Verdoorn effects. Along these well-known lines, labor productivity growth has the same sign as output growth. In addition, we assume that labor productivity will be higher, the higher energy intensity.

Agriculture—the n-sector—is fundamentally different than industry, or even agriculture in an advanced economy. With a given technology and limited fertile land, output X_n is pre-determined, and does not vary with changing levels of labor supply, L_n. However, labor *productivity* is endogenous, since a demand expansion in, say, the t-sector leads to hiring there, and a reduction of surplus labor here. Further, given output X_n, the price P_n ensures that sectoral excess demand is zero.

Energy provision—the e-sector—is modeled principally like the t-sector. An important difference is that there are neither investment nor government expenditures on e-sector product. Otherwise, the sector's firms are assumed to be large, have significant market share, excess capacity and pricing power; hence, quantity-clearing. This structure is reasonable in the short and medium run. In the long run, conventional fossil-based energy provision might well be supply-constrained and price-clearing, but we will leave that topic for future inquiry and focus for now on the medium run linkages between industrialization, food prices, and energy demand.

Nominal wages in both t and e-sector are fixed at a conventional level.[5] Since output prices P_n, P_t and P_e rise with an expansion, as does labor productivity $\xi_t = Y_t/L_t$ in the t-sector, macroeconomic distributive adjustment shows a real wage squeeze in terms of consumption goods.

3.1 Output and employment

Having broadly laid out the model's structure, we can proceed to present some more detail. The less technically inclined reader might skip this and the following subsection. Let us begin with determination of outputs. In the t-sector, real output X_t is the sum of intermediate demands, consumption C_t, investment I_t, government expenditures G_t and exports E_t:

$$X_t = \sum_i^3 a_{ti} X_i + C_t + G_t + I_t + E_t. \tag{2}$$

Total consumption of t-sector product decomposes by sources of demand, $C_t = C_t^T + C_t^N$, where subscripts denote the type of product, and (capitalized) superscripts the origin of demand for that product. Note the aggregation scheme: T-households earn (after-tax) wage income from t and e-sectors and consume all of it; N-households earn (after-tax) wage income from the n-sector and consume all of it; C-households earn (after-tax) profit income from t and e-sectors and save all of it.

Analogous to equation(2), e-sector output is demand-determined,

$$X_e = \sum_i^3 a_{ei} X_i + C_e^T + E_e, \tag{3}$$

with the difference that n-sector households do not consume (significant amounts of) energy, so that $C_e^N = 0$. In contrast to t and e-sector, the level of n-sector output is capacity-constrained, and just proportional to inherited capital:

$$X_n = \gamma K_n = \bar{X}_n. \tag{4}$$

Value added in the three sectors is proportional to real outputs. We can write the share of domestic value added in supply as

$$\mu_j = \frac{Y_j}{X_j} = 1 - \left(\sum_i^3 a_{ij} + t_j^X + f_j e\right), \tag{5}$$

where t_j^X is a production tax net of subsidies, $f_j = M_j/X_j$ is the sectoral import propensity and e is the nominal exchange rate, quoted as the domestic currency price of a unit of foreign currency. The assumption implicit in this specification is that value added is proportional to supply, and that this ratio changes only following changes to the input-output coefficient a_{ij}, changes to tax policy t_j^X, and trade and exchange rate changes. As will be seen further below, such trade and exchange rate effects are what drive changes in energy productivity.[6]

Export and import demand *can* be responsive to price changes; in standard fashion export and import functions are

$$M_j = \phi_j^0 \rho_j^{-\phi_j} X_j \tag{6}$$

[5] Conventional wage levels w_t and w_e are currently calibrated to unity in the base year data. These could be extended to include a fixed premium on the agricultural wage w_n.

[6] Note as well that equation (5) is a behavioral assumption, since it does not satisfy the accounting constraint of the cost decomposition, or the sectoral column sums 1-3 in the SAM. A common alternative to the proportionality assumption applied here is to use an Armington CES-aggregate of domestic supply and imports, from which the optimal demand share of value added in total supply can be derived. See

$$E_j = \varepsilon_j^0 \rho_j^{\varepsilon_j} W_j, \quad (7)$$

where $\rho_j = \frac{eP_j^*}{P_j}$ is the sector"s relative price with eP_j^* the foreign price in domestic currency, and P_j the domestic goods price. W_j represents world demand for j-sector product; $W_n = 0$. As discussed below, price elasticities of import demand ϕ_j and export demand ε_j can vary substantially across sectors.

Investment and government expenditures on t-sector product are exogenous. Consumption is determined by a standard Linear Expenditure System (LES). Recall that only wage earners consume; we discuss profit income in a moment. Modern wage-earning households—denoted by the superscript T—are comprised of those working in the t and e-sectors. Their disposable income is $Y_d^T = (1-\pi_t)(1-t_t^T)P_tY_t + (1-\pi_e)(1-t_e^T)P_eY_e$, where $\pi_i = 1 - \frac{w_iL_i}{P_iY_i}$ for $i = t, e$ is the sectoral capital share, and t_i^T is the (net) tax rate on sectoral wage income. T-households demand all three goods, and consume a minimum "floor" amount of n-sector product, C_F^T. We list the equations here for completeness.

$$C_t^T = c_t^T \frac{Y_d^T - P_nC_F^T}{P_t} \quad (8)$$

$$C_e^T = c_e^T \frac{Y_d^T - P_nC_F^T}{P_e} \quad (9)$$

$$C_n^T = (c_t^T + c_e^T)C_F^T + (1 - c_t^T - c_e^T)\frac{Y_d^T}{P_n}. \quad (10)$$

Analogously, n-sector households disposable income is $Y_d^N = (1-t^N)P_nY_n$, and their floor consumption of n-sector product is C_F^N:

$$C_t^N = c_t^N \frac{Y_d^N - P_nC_F^N}{P_t} \quad (11)$$

$$C_n^N = c_t^N C_F^N + (1 - c_t^N)Y_d^N. \quad (12)$$

Fixed real n-sector income implies that consumption demand for n-sector product from these households is fixed, as well. It follows that a rise of intermediate demand for X_n can be satisfied only if modern households shift away from consumption of food. As will be seen in the discussion of simulation results below, high levels of food consumption can significantly constrain the system. It should as well be noted that the budget shares in the SAM imply out-of-date Engel elasticities. We further do not estimate behavioral elasticities (i.e. trade price elasticities), but use commonly applied magnitudes. In the following section we discuss the role of different elasticities, and sensitivity of model results to changes of elasticities.

Profit income is the sum of profits generated in t and n-sectors. We denote profit-earning households with the superscript C. Their income is $Y^C = \pi_tP_tY_t + \pi_eP_eY_e$, and their savings—the sole source of private savings—is equal to a constant fraction s_π of Y^C. Profit income is taxed at the rates t_t^C and t_e^C in the two sectors, respectively.

Finally, let us consider the labor market. Employment in industry and energy rises with demand. As rates of capacity utilization increase, labor demand increases. We define the following relationship

$$L_i = \frac{Y_i}{\xi_i} \quad (13)$$

for $i = t, e$ and with ξ_i equal to sectoral labor productivity—assumed constant for the energy providing sector, but endogenous and pro-cyclical in industry. (Since labor productivity plays a crucial role in the determination of the distribution of income, we discuss it in the next section.) The n-sector, however, must absorb all surplus labor:

$$L_n = L - L_t - L_e, \quad (14)$$

where L is the constant labor force. An important implication is that there is no unemployment, but only disguised *under*employment in the agricultural sector.

3.2 Prices and distribution

The model features three sectoral output prices (P_t, P_n, P_e), three sectoral value added prices (Z_t, Z_n, Z_e), three nominal wage rates (w_t, w_n, w_e), and a set of two profit rates (r_t, r_e) and two corresponding sectoral profit shares (π_t, π_e).

Let us begin with prices of e and t-sector output. Prices are cost-determined. Defining $\nu_i = 1 - a_{ii} - t_i^X$, we can write the output price as a weighted average of all cost components—domestic intermediates, the factor cost index Z and imported inputs:

$$P_i = \sum_{j,j\neq i}^{3} \frac{a_{ji}}{\nu_i} P_j + \frac{\mu_i}{\nu_i} Z_i + \frac{f_i}{\nu_i} e P_i^*. \quad (15)$$

The corresponding value added prices for $i = e, t$ are

$$Z_i = \frac{1}{1-\pi_i} \frac{w_i}{\xi_i}, \quad (16)$$

where w_i/ξ_i are sectoral nominal unit labor costs and $1/(1-\pi_i) = 1 + \tau_i$ are sectoral mark-up factors.

The price of n-sector output responds to excess demand. Since X_n is exogenous, P_n clears excess demand in the sector, and thus is proportional to

$$P_n \propto \sum_i^3 a_{ni} X_i + C_n^T + C_n^N - X_n, \quad (17)$$

whereas the net price Z_n clears the cost decomposition, and can be written as

$$Z_n = \frac{(1 - a_{nn} - t_n^X)}{\mu_n} P_n - \sum_{j,j\neq n}^{3} \frac{a_{jn}}{\mu_n} P_j. \quad (18)$$

Further, in the n-sector, the nominal wage varies to clear the income-value added identity, so that

$$w_n = \frac{Z_n Y_n}{L_n} = P_n \xi_n, \quad (19)$$

which of course implies that the real agricultural wage grows at the rate of n-sector labor productivity growth. In summary, in the n-sector, P_n responds to demand; Z_n responds net income per unit, in other words, to the excess of P_n over costs; and w_n responds to Z_n and labor productivity.

Nominal wages in t and e-sectors are exogenous, but profit rates vary with the distribution of income and economic activity. The two sectoral profit rates are allowed to differ—since the model describes the short to medium run, and sectoral capital stocks are assumed fixed, sectoral profit rates can differ. Since the e-sector uses accumulated t-sector output as capital, the rate of profit must be adjusted for the relative price. From the definition of the capital share, the profit rates can then be written as

$$r_t = \pi_t \frac{Z_t Y_t}{P_t K_t} \text{ and} \quad (20)$$

$$r_e = \pi_e \frac{Z_e Y_e}{P_t K_e}. \quad (21)$$

The functional distribution of income in t and e-sectors is fixed; in other words, the mark-up rates τ_t and τ_e are exogenous.

In the t-sector, further, labor productivity ξ_t is endogenous. Following the literature on the Kaldor-Verdoorn Law, we assume that labor productivity increases with demand

$$\xi_t = \delta_t^0 \left(\frac{Y_t}{K_t}\right)^{\delta_t^1} \left(\frac{E_t}{L_t}\right)^{\delta_t^2}, \qquad (22)$$

but further energy intensity, or the ratio of energy use in the sector E_t to labor in the sector L_t.

Lastly, we have to aggregate. The overall profit share π is just total profit income as a share of aggregate GDP, $P_y Y$. The GDP-deflator P_y is calculated as a Fisher-index of the three sectoral prices.[7] The real exchange rate index ρ is the ratio of the (import-)weighted average of import prices in domestic currency to P_y.

4. Simulation Results and Discussion

In this section, we discuss simulation results. Three scenarios are considered. First, investment demand expansion in the t-sector represents a demand shock. A wage increase in the t-sector and an increase in world energy price P_e^* represent price shocks. The results are summarized in Tables 4-6, the first of which shows overview statistics, and the second statistics on energy demand, productivity and intensity. Table 6 show more detailed statistics on (sectoral) prices and distribution, and (sectoral) allocation of output, labor and product demands, respectively.

Before delving into the numbers, let us briefly consider the baseline calibration. First, we assume that imports in the agricultural and energy sector do not respond to real exchange rate changes, meaning $\phi_n^1 = \phi_e^1 = 0$. With Egypt's reliance on food and oil imports in mind, this seems not to be an overly restrictive short-run assumption. Further, price elasticities of import and export demand for t-sector goods are more responsive to price changes; $\phi_t^1 = -0.6$ and $\varepsilon_t^1 = 0.6$. The export price elasticity of energy demand is lower at $\varepsilon_e^1 = 0.2$, since the rest of the world is as well dependent on energy provision independent of its price. The implicit assumption is that the rest of the world is more flexible; i.e. that it is easier for the rest of the world to substitute away from Egypt's energy exports, than it is for Egypt to substitute away from the rest of the world's. While that might be considered a defensible assumption, it is not driving simulation results. As will be detailed below, the structure of the model is more important in determining patterns of energy productivity and intensity, than any particular elasticity.

Other behavioral parameters concern the labor productivity rule in the t-sector and the linear expenditure system. The Kaldor-Verdoorn elasticity, as introduced above. $\delta_t^1 = 0.35$ is the Kaldor-Verdoorn elasticity; and $\delta_t^2 = 0.2$ the elasticity on energy intensity. Engel elasticities of the linear expenditure system depend on budget shares of the base year SAM data and the assumed food consumption of n-sector product. (Recall that food consumption of t and e-sector product is zero.) We assume $CFT/C_n^T = 0.2$, and $CFN/C_n^N = 0.6$, so that only one fifth of n-sector demand from T-households is invariable to changes in their real income, but three fifth of n-sector demand from N-households.

4.1 Investment shock

We can first consider the investment shock in more detail. In this scenario, (exogenous) real investment demand in the t-sector (I_t) is increased by roughly six percent—which represents

[7] The Fisher-index is the square root of the product of Laspeyres and Paasche indexes, with base year quantities and post-shock equilibrium quantities as weights, respectively.

one percentage point of GDP. The upper part of Table 4 shows net lending flows relative to GDP of the private and public sector, and net borrowing relative to GDP of the foreign sector.[8] The first column shows the base year ratio in percentage points, and the following columns the ratios resulting from the shocks applied.

In response to the investment shock, the private balance swings by a bit more than six tenth of one percentage point relative to GDP, from a surplus to a deficit. The expansion increases revenues, so that the government's surplus increases by almost a tenth of a percentage point relative to GDP. The new investment is financed from abroad, and the current account worsens by a bit more than half a percentage point relative to GDP, but remains in surplus.

The lower sections of Table 4, and Tables 5-6, corroborate this first impression. The demand expansion in the t-sector leads to growth of output in that sector, and the accompanying (slower) growth of labor demand. Labor demand can be satisfied at the conventional wage w_t out of existing labor surplus in the n-sector. Structural change is set in motion; the t-sector employment share rises. With fixed mark-up rates in the t-sector, the net price Z_t falls with the demand-induced productivity increase, and the aggregate profit share exhibits a small negative change.

Following the labor transfer from the n-sector to the t-sector, average productivity in agricultural activities rises. Since (intermediate) demand for n-sector output rises as well, the price P_n increases to balance demand and fixed supply. The nominal wage grows with inflation and the rise in productivity; the real wage w_n/P_n grows at the rate of labor productivity growth.

Overall, the spike in *Pn* drives inflation inflation.. See Table 4, bottom, and Table 6. The food-to-manufactures price ratio jumps. This inflation leads to some real appreciation and results in a decline of net real exports.[9]

Changes in consumption demands play an essential role in the adjustment to the shock. See Table 6. Specifically, consumption demand for n-sector product has to fall in order to free up resources for increased intermediate input demands from the other two—expanding—sectors. Importantly, the rise in the food-to-manufactures price ratio outweighs the increase in real income of the t-sector household, reducing its consumption demand C_n^T for n-sector product. Conversely, the rise in the price ratio P_n/P_t allows an increase in t-sector product consumption of the N-household, so that C_t^N rises.[10]

4.2 Price shocks

Let us now consider wage policy.[11] A nominal wage shock ($\hat{w}_t > 0$) of ten per cent in the t-sector has significant effects on private, public and foreign balance. Private balance worsens by one fifth of a percentage point of GDP; the public balance worsens by one tenth of a percentage point of GDP. The foreign sector reduces its net borrowing by the sum, about three tenth of a percentage point of GDP; meaning net exports fall.

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[8] Private and public balance are reported as *leakage less injection* ($S - I, T - G$) and the foreign balance as *injection less leakage* ($E - M$) because we are accustomed to think in terms of the resulting signs.

[9] The growth rates of real imports reported in the lower part of Table 7 are import flows valued at foreign prices in domestic currency, and deflated by the sector's domestic output price. As mentioned above, $\phi_n^1 = \phi_e^1 = 0$, and $\hat{X}_n = 0$.

[10] Indeed, the fall in C_n^T has to be sufficiently large to enable the expansion in t and e-sector production. High food consumption levels of n-sector product by t-sector households leads to a strangling bottleneck: If C_n^T can not adjust, the burden falls on Y_t—the investment expansion leads to inflation, *lower output* of industry, and a more unequal distribution of income.

[11] Due to the relatively small size of the e-sector wage bill, wage increases in this sector have overall limited effects, albeit with the same signs as the increase in w_t. We focus here on the increase in w_t.

Indeed, the real exchange rate appreciates by almost nine per cent. Nominal wage inflation, which feeds into t sector prices, plays the key role here. The resulting reduction in net exports drives results in this scenario, since it outweighs the consumption increase of t-sector households. The contraction in t-sector output leads to *reverse* labor transfer, and the n-sector must re-absorb labor surplus. Accordingly, t-sector employment and output share fall. As can be seen in Table 6, Y_e increases. The reason is that the nominal wage shock feeds through to P_t, so that Y_e becomes relatively inexpensive, and consumption demand for e-sector output rises.

An increase to the world price of energy P_e^* works in similar ways. Of course, the foreign price increase triggers a real depreciation. However, the net export effect is quite muted, and the ratio of current account to GDP *falls*. The reason is two-fold. First, energy exports increase, since they trade off in world markets against the now higher world price. Since the energy sector overall is small, however, this effect does not dominate. Second, t-sector output price inflation is positive—even if small—due to the cost shock from the energy sector. Resulting inflation leads to reduced net exports in the sector, which, due to its relative size, drives a—even though small—contraction of aggregate GDP.

4.3 Energy demand, productivity and intensity

What, all the while, happens in the energy sector? Table 5 summarizes aggregate and sectoral detail on energy demand, productivity and intensity. *Energy producivity* refers to value added per unit of energy, and *energy intensity* to energy per unit of labor. The sum of the growth rates of energy producticity and energy intensity is (approximately) identically equal to the growth rate of labor productivity. Where, in our simple three sector model, do aggregate labor productivity increases stem from—increases in the productivity or intensity of energy?

The answer to this question depends in part on how we define *energy*. First, and in contrast to many other studies, we do not specify the physical energy content of the energy sector's output. We simplify by considering only the (real) value added of the sector Y_e.[12]

The top part of Table 5 shows these measures in the aggregate: energy productivity, i.e. total GDP Y relative to total energy sector value added Y_e; and energy intensity, i.e. total energy sector value added Y_e relative to total labor L. Let us first recognize the pattern across these examples, and then delve into details. Energy intensity shows positive growth across all three examples, and energy productivity growth is positive following the investment shock and negative in the other two examples. Across these examples, energy intensity rises faster than energy productivity, if the latter is positive at all. In that sense, these results correspond with the historical pattern that aggregate labor productivity growth is driven by increases in energy intensity, rather than energy productivity.

A more detailed look at the numbers reveals that this result is implicit in the structure of the model. The aggregate statistics simply report what is happening in the energy sector—energy productivity as defined here is the inverse of the energy sector value added share, and growth of energy intensity is equal to growth of value added, given our assumption that aggregate labor L is constant. That means as well that the result of the third example, the world energy price increase, is driven by trade elasticities. With a positive export response, but no import response, value added in the e-sector rises, and the sector's share rises or energy productivity falls, and energy intensity rises. If we set the export price elasticity in the sector to zero (as the import price elasticity), the sign pattern reverses. The consumption demand decrease for

[12]Specification of physical energy content becomes necessary when pollution mitigation is included in the model, since greenhouse gas (GHG) emissions of energy provision than matter. As discussed in the introduction, this paper is primarily concerned with the linkages and bottlenecks between these three stylized sectors of a developing economy.

e-sector output due to the imported price spike dominates; the sector's share falls or energy productivity rises, and energy intensity falls.

The other two examples are driven through similar channels, even if not dominated by the trade elasticities. In the first example, the t-sector expansion implies a fall in e-sector value added share or an energy productivity increase. The second example rests on the shift in consumption demand. Inflation in the t-sector leads to a shift of consumption towards e-sector output; further, the net export decrease in the e-sector is smaller than in the t-sector, which in combination leads to an increase in the share of e-sector value added or a decrease in energy productivity.

At the sectoral level, shifts in labor demand matter. Energy productivity in the n-sector does not change, of course, since output in the sector is constant, and so is the intermediate energy demand. Energy productivity in the t-sector changes with the change in μ_t. Recall that μ_t is the share of domestic content in t-sector output. It follows that growth of labor productivity is the sum of a *trade effect* and a *labor effect*, where the former drives growth of energy productivity and the latter growth of energy intensity.

The trade effect drives energy productivity, since the ratio of sectoral value added Y_i to that sector's energy use $a_{ei}X_i$ cannot change with a_{ei} but only with exports. The labor effect drives energy intensity since the sector's energy use $a_{ei}X_i$ is determined by X_i, but the sign of sectoral employment growth will determine sign (and magnitude) of the growth rate of energy intensity. Further, growth of energy intensity in the t-sector depends on the Kaldor-Verdoorn elasticity. Setting $\delta_t = 0$ (still with trade "turned off" as well) renders $\hat{X} = \hat{Y} = \hat{L}$, and growth of energy is zero.

The aggregate effects in that most basic setting then depend entirely on (1) the type of the shock and (2) the labor transfer effect. Nevertheless, with or without trade effects, and with or without a Kaldor-Verdoorn productivity rule, *industrialization is possible only with increasing aggregate energy intensity*. The majority of the rise in aggregate labor productivity stems from increases in energy intensity, rather than energy productivity.

5. Conclusion

This paper presents a fairly standard model of a developing economy augmented by an energy providing sector. We analyze the links between industrialization, the agricultural supply constraint, and energy use as well as its implications for climate mitigation policies. The discussion focuses on the fact that labor productivity growth must stem from either increases in energy productivity or energy intensity. Results show that—across a number of different parameterizations—aggregate labor productivity growth is driven by increased use of energy.

Obviously, this result is implicit in the model's structure: it ultimately rests on the fixed coefficient input-output matrix. In that sense, the exercise highlights the inherent tension between growth and climate mitigation, since successful climate mitigation requires a reduction in (fossil) energy input coefficients.

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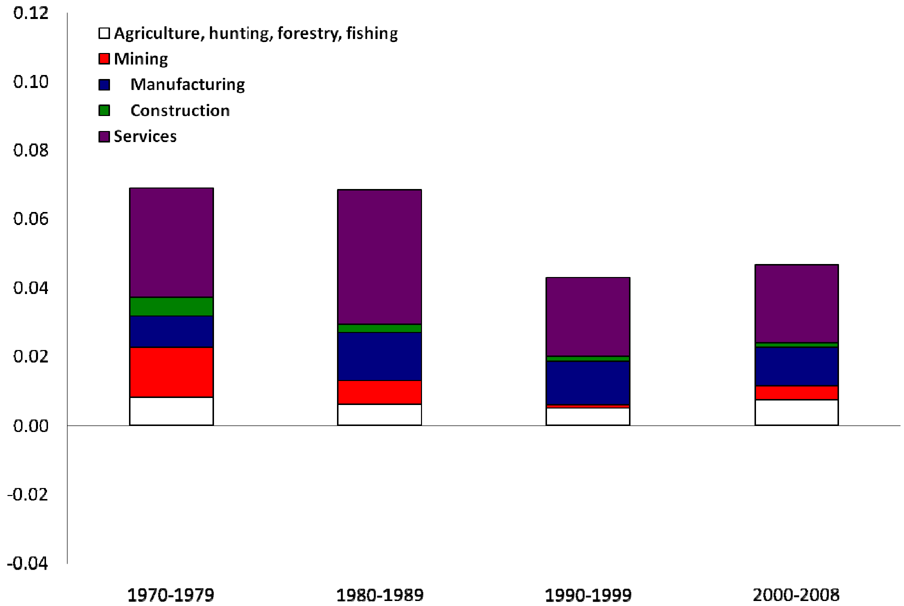
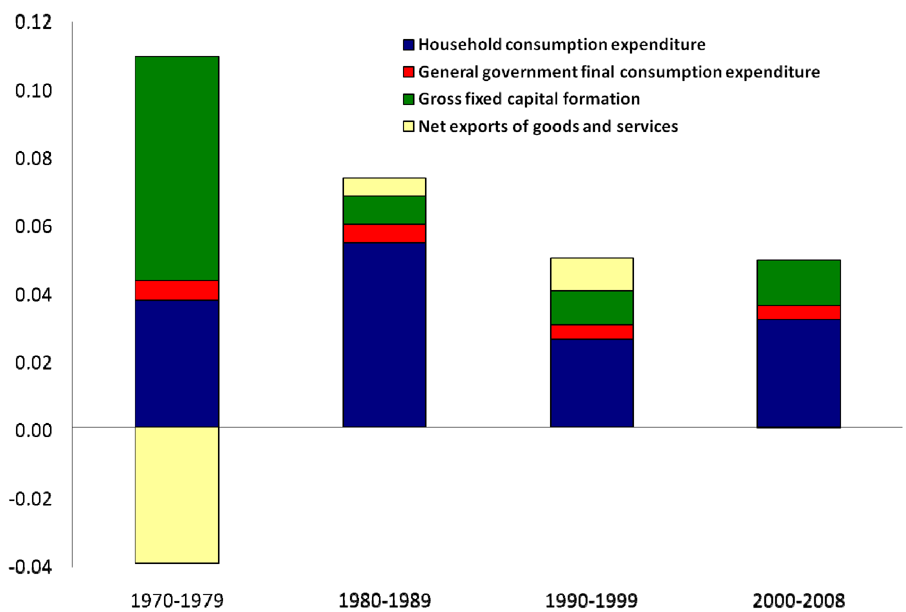
Figure 1: Sectoral Contributions to Aggregate Output Growth, Egypt 1970 – 2008



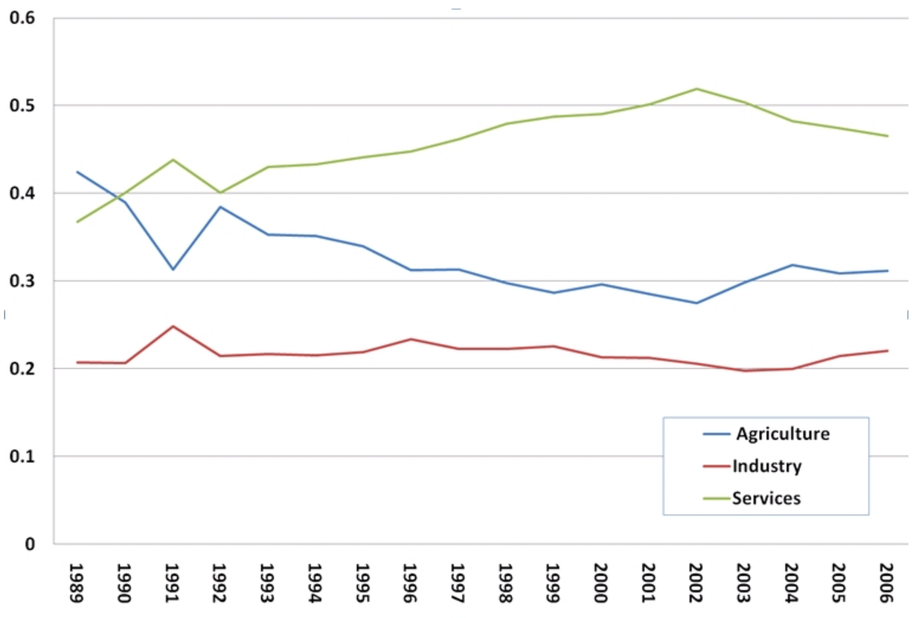
Source: UN SNA and author's calculation.

Figure 2: Contributions to Growth of Aggregate Demand by Institutional Sectors, Egypt 1970 – 2008



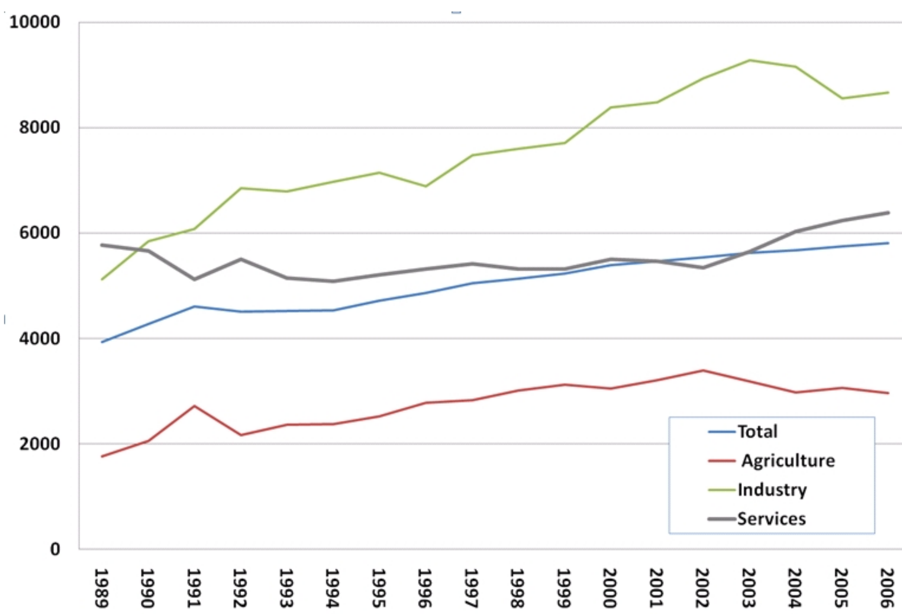
Source: UN SNA and author's calculation.

Figure 3: Sectoral Employment Shares, Egypt 1989 – 2006



Source: ILO Global Employment Trends (GET) and author's calculations

Figure 4: Sectoral Productivity Levels, Egypt 1989 – 2006



Source: ILO Global Employment Trends (GET) and author's calculations

Table 1: Social Accounting Matrix (SAM) for Egypt 1996/1997

	Costs			**Consumption**			**Gov**	**Foreign**	**Inv**	Sum
	T	**N**	**E**	**T**	**C**	**N**				
T	131.6	9.2	5.6	117.4		40.2	29.6	54.9	45.2	434
N	25.7	11.3	0.0	23.7		8.1				69
E	12.1	0.1	0.4	3.4				13.1		29
Wages	154.0	51.7	1.8							207
Profits	42.2		15.6							58
Government	17.7	-9.4	0.0	11.2	11.4	3.4				34
Foreign	50.5	5.9	5.7							62
Flows of funds					46.3		4.7	-5.9	-45.2	0
Sum	434	69	29	156	58	52	34	62	0	

Table 2: Macroeconomic Indicators Based on SAM (Table 1)

Indicator	
Modern Sector (% of GVA)	0.78
Traditional sector (% of GVA)	0.15
Energy sector (% of GVA)	0.06
GFCF (% of GVA)	0.17
Current account balance/GDP	0.02
Household consumption of modern good	0.82
Household consumption of traditional good	0.17
Household consumption of energy	0.02
Capital income of the traditional sector (percentage of total capital income)	0.08
Wage income of the traditional sector (percentage of total wage income)	0.15
Overall traditional income of total income (wages, profits and land incomes)	0.18

Table 3: Leontief Inverse Matrix

	t	**n**	**e**
t	1.49	0.21	0.26
n	0.11	1.21	0.02
e	0.04	0.01	1.02
Multiplier	**1.65**	**1.42**	**1.30**

Table 4: Simulation Results – Macroeconomic Statistics

		1 t-sector investment	2 t-sector wage	3 Foreign energy price
Macroeconomic balance: Shares to GDP				
(S-I)/GDP	0.43	-0.27	0.20	0.42
(T-G)/GDP	1.79	1.94	1.73	1.78
CA/GDP	2.22	1.67	1.92	2.20
	0.00	*0.00*	*0.00*	*0.00*
Shares: Change in percentage points				
Lt/L		1.22	-0.77	-0.08
Yt/Y		0.42	-0.34	-0.05
pi		-0.24	-0.37	0.04
Growth rates				
Y		1.96	-1.14	-0.10
Py		0.71	9.69	-0.04
Pn/Pt		5.53	0.36	-0.41
w/Py		2.26	-0.69	-0.14
w/Pn		-2.31	0.47	0.13
RER		-0.70	-8.84	4.96
xin		5.20	-2.98	-0.30
xit		0.88	-0.56	-0.06

Notes: The top part of the table reports private, public and foreign balances. The middle part reports changes in percentage points of t-sector employment and output share as well as the aggregate profit share. The bottom part collects a set of relevant growth rates.

Table 5: Simulation Results – Energy Demand, Intensity and Productivity

	1 t-sector investment	2 t-sector wage	3 Foreign energy price
ENERGY			
Aggregate: e-Sector value added			
Y/Ye	0.70	-1.68	-0.48
Ye/L	1.25	0.55	0.39
(Intermediate)			
Energy productivity			
Yn/E(n)	0.00	0.00	0.00
Yt/E(t)	0.02	-1.23	-0.01
Energy intensity			
E(n)/L(n)	5.20	-2.98	-0.30
E(t)/L(t)	0.86	0.67	-0.04

Notes: The top part of the table reports aggregate energy productivity and energy intensity, which sum to aggregate labor productivity growth. The lower sections show the equivalent statistics for n- and t-sector.

Table 6: Simulation results – Prices and distribution

	1 It	2 wt	3 Pef		1 It	2 wt	3 Pef
PRICES & DISTRIBUTION				**OUTPUTS**			
Pn	5.42	8.43	-0.31	Y	1.96	-1.14	-0.10
Pt	-0.12	8.06	0.10	Ye	1.25	0.55	0.39
Pe	-0.02	1.58	2.01	Yt	2.54	-1.59	-0.16
Ze	0.00	0.00	0.00	Xe	1.25	0.55	0.39
Zn	7.03	9.47	-0.43	Xt	2.52	-0.37	-0.15
Zt	-0.87	10.62	0.06	Et	0.07	-4.55	-0.06
Py	0.71	9.69	-0.04	Ee	0.00	-0.31	1.52
rt	1.76	0.74	-0.20	Me	1.27	-1.01	8.25
re	1.36	-6.96	0.29	Mn	-5.14	-7.77	0.32
we	0.00	0.00	0.00	Mt	2.57	-3.42	-0.19
wn	12.59	6.20	-0.73	CeT	1.53	7.09	-2.06
wt	0.00	10.00	0.00	CnN	0.68	0.43	-0.05
w	2.98	8.94	-0.18	CnT	-2.96	0.26	0.18
e	0.00	0.00	0.00	CtN	7.33	1.41	-0.54
ro	-0.70	-8.84	4.96	CtT	1.63	0.66	-0.19

Notes: This table summarizes further statistics of the simulation results.